www and Facility Electric Power Management

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Abstract
Managing the use of electrical energy is a prerequisite to cost effective business performance. Utility deregulation has created opportunities for the facility manager to reduce the cost of electricity. Not the least of which, is the strategic use of installed generation capacity, emergency and standby power systems. The **W**orld **W**ide **W**eb provides commerce and industry with a whole new dimension in conducting business. This paper explores the impact that the **www** can and has had on orchestrating the cost effective dispatch of alternate electric energy strategies.

Introduction
"eBay.com", "priceline.com" and others have brought the public to a new level of awareness of the Internet. Of course, engineering, science and business have been exercising computer capabilities to their limits for decades. Microsoft asks the question "Where do you want to go today?" Accenture advertises "Now it gets interesting." That last, is probably the most telling of all. With the availability of the World Wide Web, imagination is truly the only impediment limiting departures from the common day practice.

There is a certainty! The cost of electricity is increasing. The means to control that cost is to let it operate in the market place as a commodity. However, the shift from a regulated to a non-regulated industry can have some serious short-term ramifications, as the course is traveled to a free market electrical environment.

Proliferation of the www and micro-processor based products has had a burgeoning effect on the demand for electricity. Electric demand in some geographic areas has absolutely exploded. The expansion of electric generation in some of these areas has not kept pace with the growth in demand. As a result, what was a generation safety margin became the source to carry this new demand. Thus, when demand growth in neighboring areas or natural occurrences, i.e. lack of rainfall in hydroelectric regions, reduced available generation capacity, some areas were left with little to no reserve capacity. This resulted in rolling blackouts during high demand peaks. Consequently, businesses were forced to close or find other means to meet their needs. Those businesses that had emergency or standby power systems were able to mitigate the impact of reduced availability of electric energy to some degree.

It has been estimated that there are currently "…over 60,000 MW of distributed generation installed in North America in the form of reciprocating engines and gas turbines…".[1] The strategic dispatch of these resources will play a key role in maintaining business continuity and control over end user cost

[1] Little, Arthur D., Distributed Generation: System Interfaces; Arthur D. Little, Acorn Park, Cambridge, MA 02140, ©1999

of electricity as deregulation of the electric utility system moves forward.

End-User Electric Load Demand
The news media has been rife with stories and reports of excessive demands for electricity that are stressing the ability of the installed infrastructure. There are two prevalent aspects of this problem. The first is generation capacity and the second is the ability to deliver the energy to the point of need. In its simplest form, deregulation of the electric utility system seeks to separate the generation of electricity from the delivery of that commodity. In essence, under deregulation, generation is no longer regulated. However, the transmission and distribution system remains under regulation. (There is no intent herein to debate the merits of these issues. The writer accepts this fact and examines alternatives under these conditions.) To understand the generation/transmission-distribution issues, one needs to understand the driving forces.

Figure 1 is a plot of the daily electric demand profile of a light industrial facility. Note that as the working day begins, the demand for electricity increases. This demand is the rate at which electricity is used. **Figure 1** is a plot of the average demand for electricity in 15-minute intervals throughout the day. The sharp increase in the beginning of the day shows how the facility turns on. Office HVAC and production machinery is turned on just before the employees arrive and remain on until the facility closes down at the end of the day. Note that the reduction in demand at the end of the day is in distinct steps that differ from turn on. This is due to the staggered departures of employees at the end of the day. Note also that the peak demand is more than 3 times the quiescent demand of the early morning hours. The shape of this demand curve is quite typical for light industrial, commercial and office facilities.

The demand curve for the aggregate residential loads differs in that it peaks

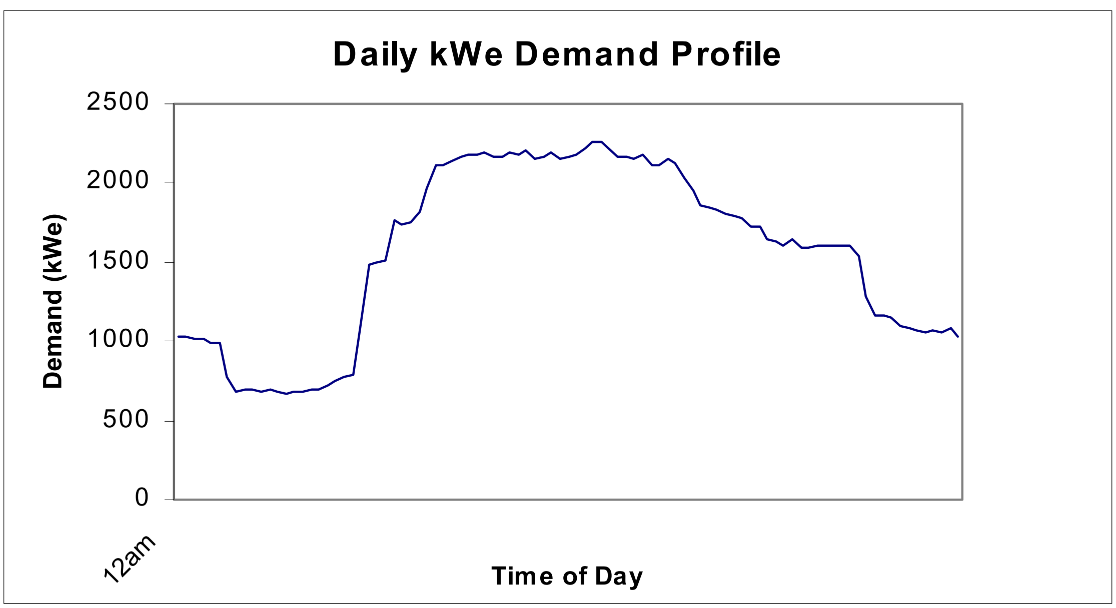

Figure 0. Typical Electric Load Demand Profile for a Light Industrial Facility

twice during the day. The first peak occurs in the early morning. The second peak occurs in the late afternoon to early evening. Intuitively, this is logical. The people who use the electricity are at home in the morning and evening and at work during the day.

The actual peaks of these demands are affected by a third factor. In areas where winter heating is the peak season, the maximum demand will occur in winter months and will be a function of the severity of the weather. In areas where summer cooling is the peak season, the maximum demand will occur in summer months and will be a function of the severity of the weather. From season to season there will be considerable variations in the peak demand. From year to year there will also be considerable variations in the peak demand.

Generation and Delivery of Electricity
There are two distinct concerns dealing with the availability of electricity at the desired point of use. Neither the generator nor the deliverer of electricity has any significant influence over where users choose to build their facilities.

Being regulated, the transmission/distribution system must provide the infrastructure to deliver electricity on demand. That is not to say that the end user is free of any costs to install infrastructure. Because no one wants to live next to a generation station, generation is typically remote from the point of use. Because demand varies throughout the day and year, generation capacity varies. Finally, because it is physically cost prohibitive to build one large generator to carry the peak demand, several generators are typically networked to provide power on a common power grid. Economies of scale and cost effectiveness of different generation techniques are commonly mixed to provide for a best cost scenario. For example, nuclear, coal and/or hydro-power may form the base load generation for a power grid. Generation

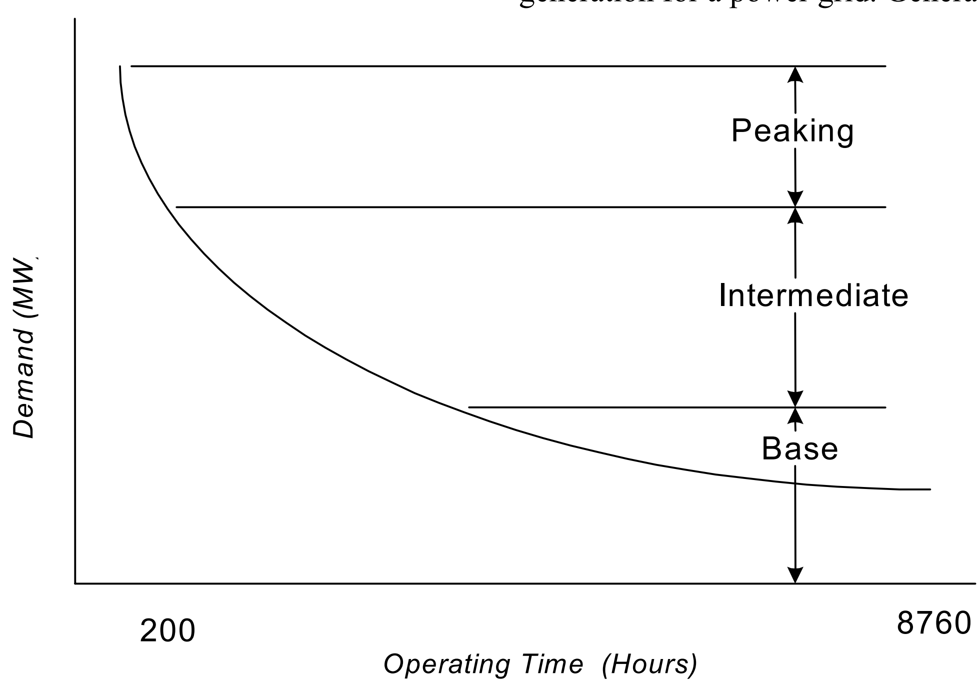

Figure 2. Generation yearly operating hours

consisting of gas fired turbines with combined cycle steam generation will form the intermediate generation and gas fired packaged peaking turbines will form the peak demand response generation. Commodity cost, electricity, is lowest for the base generation case and highest for the peaking. Affecting this commodity cost is the cost recovery of infrastructure to generate. What does that mean? **Figure 2** is an approximated plot of generation operating hours during the year. The plot illustrates that base generation operates at rated capacity for most of the year. Intermediate plants operate at rated capacity for up to 4000 or so hours per year. Peaking plants operate at capacity for up to about 200 hours per year. The cost for infrastructure of peaking plants is amortized over 200 or so yearly hours of operation. It is thus demonstrated why electricity from peaking units costs dollars per kWh while it costs cents per kWh from base generation plants. A representation of those costs is shown in **Figure 3.** This terse review establishes why those peak stress periods are so costly.

On-site Generation

The National Electrical Code, NFPA 70, Art. 700, 701 and 702 address the provisions for installation and operation of Emergency, Legally Required and Optional Standby power systems. Each of these systems are independent and capable of providing power to selected loads when the utility derived power source is inadequate. This code allows the use of these systems for peak shaving, "…The alternate power source shall be permitted to be used for peak

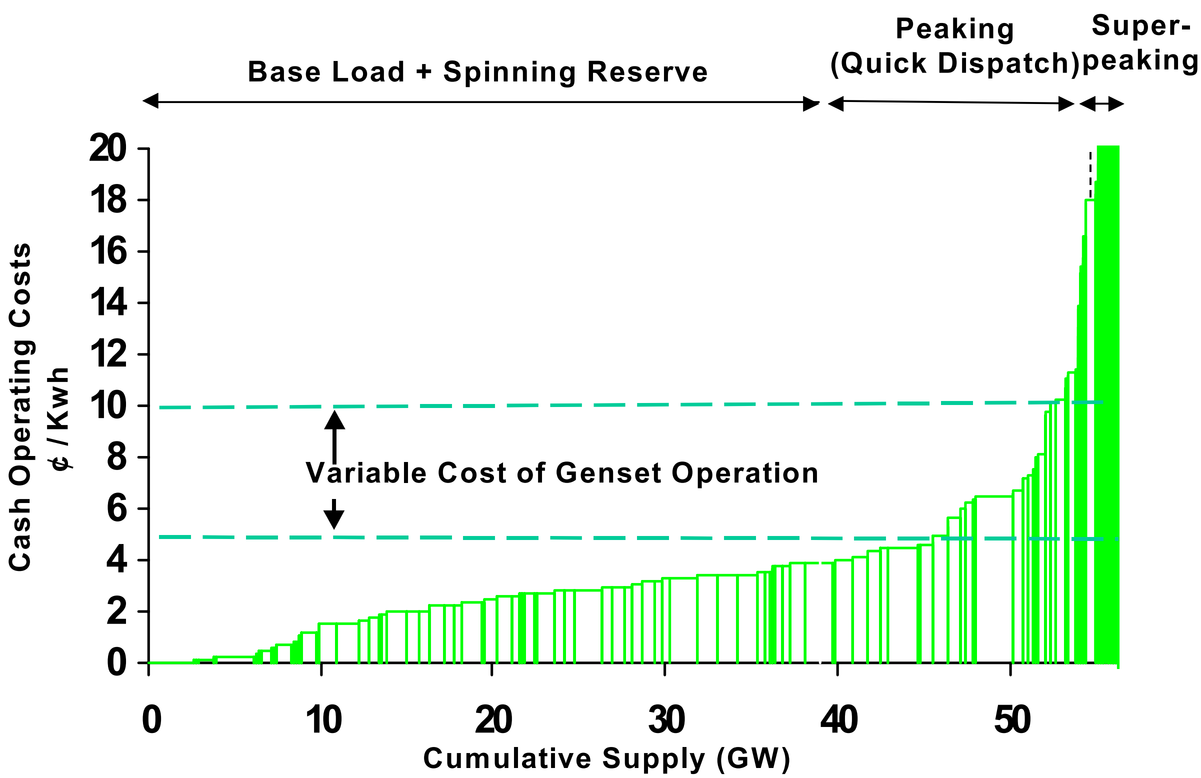

Figure 3.

load shaving…”[2] This first appeared in the NEC in the 1970’s as a result of the energy crisis at that time.

As a result of major power outages in the ‘60s’ and ‘70s’ on-site generation capability expanded. Fueling this expansion was the increasing dependence on real time data processing and computerization of business practices. As a result, there is a tremendous installed base of generation fully capable of being brought into service to address the rolling blackout issue. As a matter of necessity, these power systems are designed to start automatically and carry their respective loads whenever the utility derived voltage supply to their respective loads becomes unacceptable. So, when there is a rolling blackout on a distribution radial feeding a facility where on-site generation is installed, the protected loads will be restored to power from the alternate source automatically. This will occur in less than 10 seconds from the time the utility power is cut off. In code mandated installations, these systems must be periodically, typically monthly, exercised to confirm their availability. The reliability of these systems is very high. With over 500,000 transfer switches installed and judging by the frequency of service calls and warranty service one manufacturer experiences, reliability of these systems is well in excess of several 9’s.

These systems are installed to manage risk. As such, they are somewhat of an insurance investment. How does one determine the ROI (Return On Investment) on an insurance investment?

2 Art. 700-5(b), National Electrical Code, NFPA 70,National Fire Protection Association, Inc. One Batterymarch Road, Quincy, MA 02269, C1998

Given the existence of these systems and the allowance to use them for peak shaving, encouraged by incentives to reduce demand for short periods, additional investment in these facilities so that they can be brought into service during peaking periods is a viable consideration. The issue is what investment derives the best cost/benefit.

The Starting Point

The hypothesis is multifaceted:

1. The cost of the on-site generation is a sunk cost
2. Use of the on-site generation for peaking is self funding and yields a net positive cash flow
3. Costs to take advantage of the peaking capability of installed generation can be recovered within 3 years
4. Automation of the process is achievable with minor peripheral additions
5. Performance can be captured and verified.

The on-site power system will come in many shapes, sizes and configurations. There is a commonality however that makes it possible to resolve this multitude of configurations into three basic system types. They are:

1. Single engine single load, **Figure 4(a).**
2. Single engine multiple loads, **Figure 4(b).**
3. Multiple engines on a common bus, **Figure 5.**

These figures illustrate the breadth of on-site generation as installed for alternate power purposes. Taking advantage of this installed capacity for peaking will require:

- a means to dispatch
- load control
- verification
- operating summary
- integration with net neutral staffing.

Dispatching requires that the on-site generation be capable of being started and stopped on command. This command can issue from an in house controller or be responsive to an external signal. Deregulation of the electric utility system has spurred the growth of generation aggregators. These are businesses that make arrangements with the owners of on-site generation to pool and broker on-site resources. They will

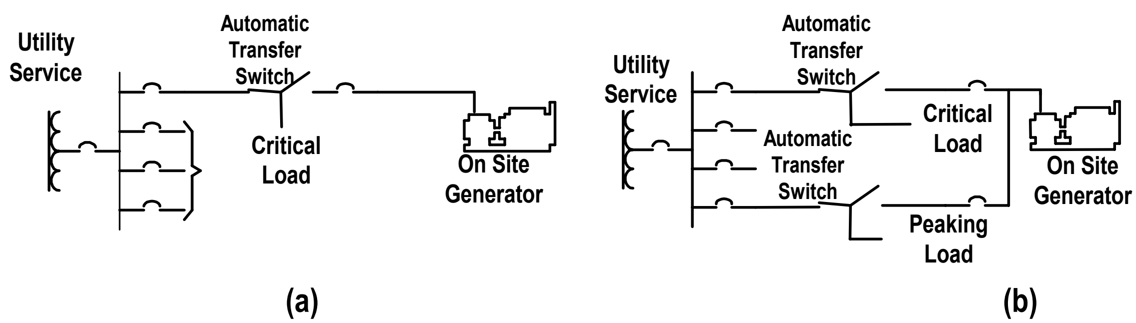

Figure 4. Simple on-site alternate power systems.

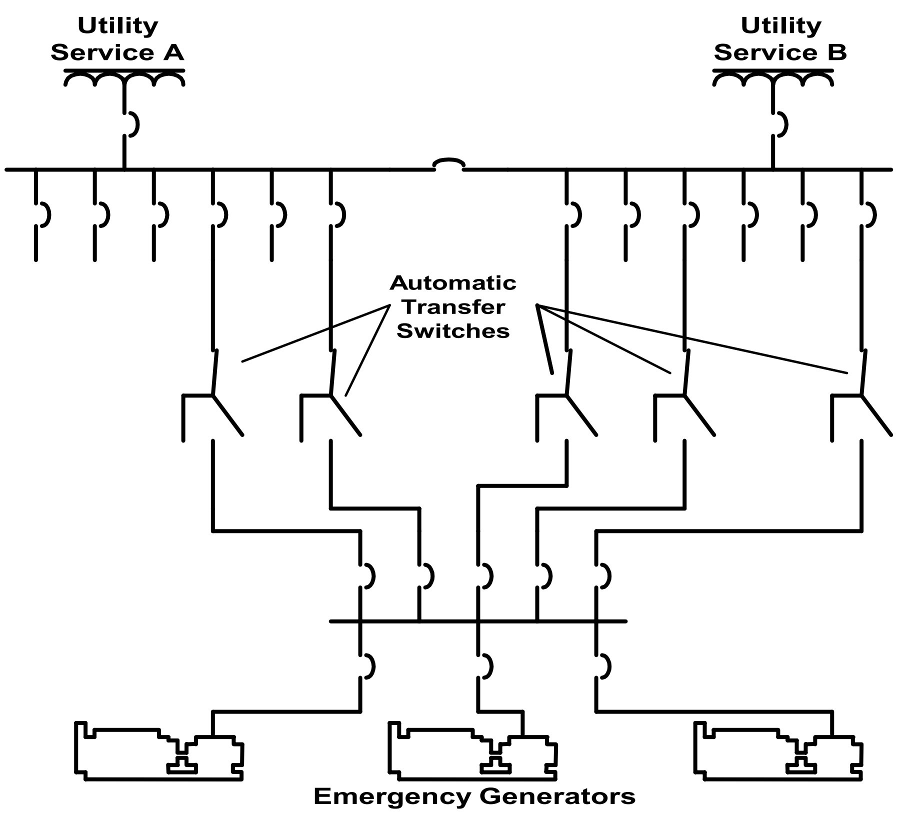

Figure 5. Multiple generator alternate power source.

aggregate several of these resources so as to achieve at least the minimum required generation capacity to permit membership in the controlling PX or ISO (Power Exchange, Independent System Operator). Typically, these require a signed contract between the PX/ISO and aggregator. The aggregator will typically require that the on-site power system be made available to him for remote dispatch. When needed, the aggregator will initiate the start and operation of the on-site resource. The agreement will settle on a capacity from the host facility. It makes no difference to the electric grid whether the demand reduction is due to load disconnect or on-site power generation, load transfer. The net effect on the demand on the grid is the same. However, the host facility is keenly interested in maintaining operations. Therefore, load disconnect is not typically a viable option.

Additionally, load transfer brings with it, the concern for operational transparency. Simply stated, regardless of the power source or switching, the load should not experience any transient conditions that would negatively impact its operation. Load transfer strategies are many and varied. Some of the variations are due to the unique nature of a load; some are a result of the unique approach a manufacturer may choose in product design; some of these to the benefit and others to the detriment of power continuity to the load. For the curious reader, a treatise on the subject of load transfer strategies can be found in a paper that was presented at an IEEE IAS Conference in the Spring of 1998.[3]

Given the typical control strategy of load transfer, all that would typically be required to initiate peaking load transfer would be an initiate signal to simulate the loss of utility derived power. This signal, delivered to the transfer switch, would cause an operating scenario exactly the same as would be initiated for periodic testing to meet code availability requirements. If the transfer strategy is suitable for system test requirements, it is suitable for peaking requirements. To determine successful operation, an auxiliary contact confirming that the load is connected to the on-site generator is all that would be required. Thus, the initiation and confirmation of operation are readily achieved. What hardware is required? For the case of the single load/single generator, a simple modem and controller would suffice. If the transfer is one of the more current product designs, it may already have communications and control capability built in. If not, the equipment required to provide this is relatively inexpensive.

Suppose, for whatever reason, the end user has an issue with using the critical load for peak demand reduction, (usually an emotional issue), it is likely that the savings from peak shaving will finance the cost of a second load transfer circuit specifically dedicated to peaking. Such a circuit is shown in **Figure 4(b).** Initiation and control would be as just described.

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[3] Daley, James M.; Load Transfer Strategies for Machine and Other Inrush Loads; IEEE Transactions on Industry Applications, VOL. 34, No. 6, November/December 1998; IEEE Operations Center, 445 Hose Lane, Piscataway, NJ 08855-1331

Where the on-site generation is comprised of two or more generator sets paralleled on a common bus, considerable flexibility and latitude is available. Typically, paralleling switchgear contains a programmable logic control system that is readily adaptable to expand the logic to accommodate peaking power scenarios. In this case, the initiate signal could be sent to the system controller or ATSE (Automatic Transfer Switch Equipment) which ever provides the most cost effective scenario. Whatever the configuration, load control is typically cost effectively achievable.

When called to operate, an aggregator will be required to confirm to the PX/ISO that he has provided the amount of contracted resource. Therefore, the aggregator will require that the host facility provide a means to measure and record the energy produced by the on-site generator during the required operating period. This verification will be a prerequisite for capacity payment. It should be kept in mind that the call for operation will be during those 200 yearly hours when the cost of other kWh is in the $s'/kWh range.

In response to this need, there are many means to record and communicate energy flow in an electric circuit. The site aggregator will likely have a predetermined arrangement for data collection and recording. The ideal data record will date and time stamp operations. In addition, it will record the kWh and demand on the on-site generation and maybe even those data on the utility derived service for the same time frame. The date and time stamped record of on-site generated kWh and kW demand would form the minimum set of data to confirm production of electricity coincident with the PX/ISO declared stress period. These records would confirm the operating summary.

What has been described thus far has not mentioned the need for increased staffing to provide on-site generation availability. In fact, the proliferation of data communications and software configurable equipment makes it all but a certainty that additional staffing will not be required. Here is where the internet comes into the picture. It is useful to explore the possibilities.

Single Generator/Single Load
Where the transfer switch is an open transition double throw device, only the load on that switch can be removed from the utility derived service. Therefore, load reduction will only equal the real time load (active load) served by that ATSE. Where the load transfer switch is either a closed transition or delayed transition transfer device that can be used as a paralleling device, the potential to take full advantage of the generator kW rating exists. Assume the latter case.[4] Figure 6 represents a single load/single generator application where the transfer switch is capable of parallel operation of the generator with the utility derived service. To adapt this installed resource to distributed generation service, one would add protective and data collecting means to the utility and generator derived feeders. Additionally, a controller would be added to orchestrate the operation on command. As **Figure 6** illustrates, a power manager has been added to the utility and generator feeders and the Soft Load Controller, SLC, has been added. There are two important points to be made here. The power managers include

[4] Note: The writer suggests that the generator be run at 80% of its standby rating when operated in the peaking mode.

protective relaying functions whose principle role is to separate the power sources immediately on the occurrence of a disturbance.

Should any failure occur in the control scenario, the installed ATSE reverts to being a transfer switch and operation for distributed generation is terminated. The ATSE can be configured to keep the load on the generator until the need for peaking is terminated. In that event, the load reduction is equal to the active load on the ATSE circuit.

As **Figure 6** indicates, the soft load controller can be accessed through the Internet. Obviously, the control will have password protection to prevent unauthorized access. It is useful to go through a typical operation. The operation begins with a remote terminal accessing the SLC to initiate a peaking operation. On initiation, the engine generator is started and the SLC controls generator frequency and voltage to match the utility derived source. The SLC then brings the generator into synchronism and initiates closure of the CE contacts. Once closed, the SLC causes the EG set to assume load. There are two modes of operation available. If islanding is selected, the EG set will take on load until the load remaining on the utility derived service is reduced to a low preset value. At that point, CN will open leaving the load on the EG set. If maintained parallel operation is selected, the EG set will take on load to some predetermined value. That value will not exceed the rating of the feeder circuit. However, it can be a value that could

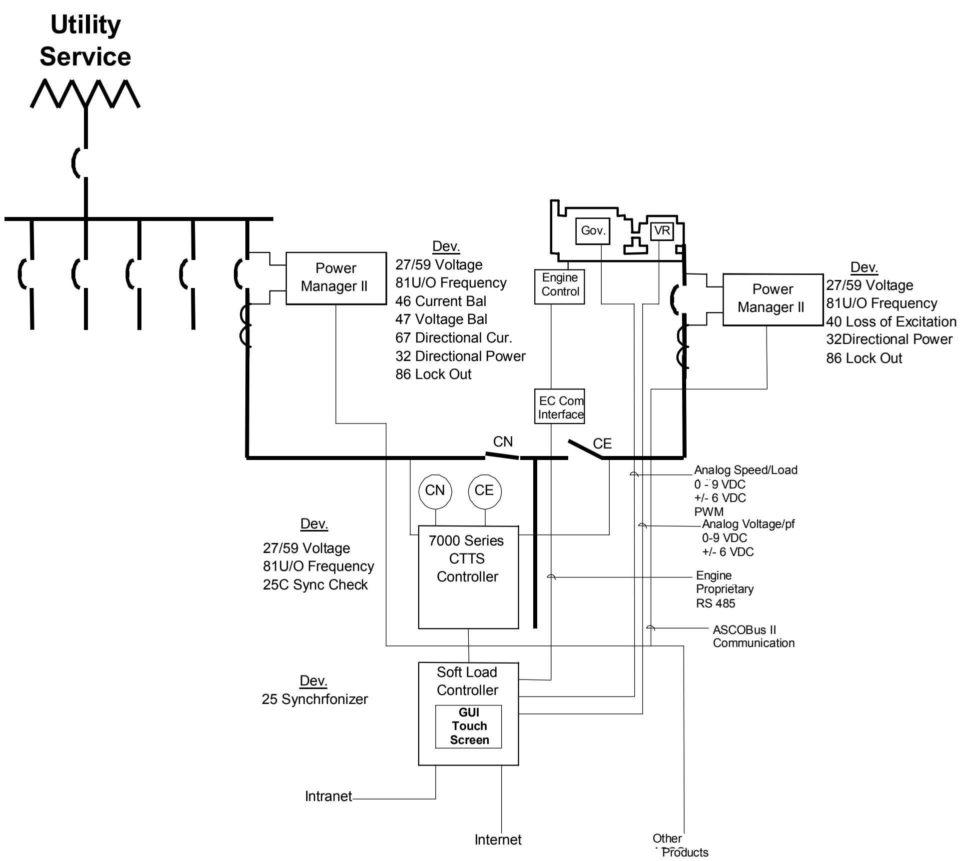

Figure 6. Global representation of the Soft Load Transfer control and communications strategy.

have a positive or negative power flow from the utility derived feeder circuit. In the maintained parallel operating mode, EG set base loading, the EG set output increases to a value. If the load of the ATSE exceeds that value, then the utility derived circuit will provide the additional power required by the load. If the load of the ATSE is less than that value, then the excess power will flow into the switchgear bus to which the utility derived feeder is connected. Given that the load of the facility will exceed the EG set output, while none of this excess power will flow into the grid, it will serve to further reduce the facility demand on the grid. Thus the major advantage of the base load operation is revealed. Regardless of the real time power demand of the ATSE load, a fixed, maximized facility demand reduction is made available for DR (Distributed Resource) service. This operating mode has the maximum return on the incremental invested capital to achieve DR service. The incremental capital investment to achieve this operation can be in the $10 k to $20 k range.

Multiple Loads/Multiple Generators
Increasing need for power reliability has caused many facilities to install multiple EG sets to meet the expanded standby power needs of important loads. **Figure 7** provides and illustrative example of such a facility. Obviously, power systems of this size provide major opportunities for peaking operation. In the system shown, the installed standby power infrastructure can be brought into operation for peaking either by transferring the loads to the on-site power bus or by adding a circuit for paralleling the on-site power bus with the utility derived power bus. The advantage of parallel operation is that it provides for full use of the EG set capacity. The advantage of load transfer is that it minimizes the incremental investment to make the on-site power system available for peaking service. Load transfer peaking will require power managers with protective functions as previously discussed and an SLC.

Net Access
Referring back to **Figure 6**, note that the SLC has communications capability for intra or internet access. Where the SLC operates in a windows environment, there exists the opportunity to provide icon interface that makes operator use less foreboding. Such operating environments will typically provide adaptable formats. Communications are adaptable to a variety of data processing needs.

From the facility manager's point of view, the computer sitting on his desk can be booted with the necessary software that enables the communications in a windows environment that would allow him to tailor the performance to meet his needs. He may wish to be able to initiate the operation at will, from his computer. In this case, using his password access, he could:

- Call on the generator to start, synchronize, parallel and take on load
- Call on the generator to start and initiate load transfer
- Vary the load to meet the real time need
- Structure an operating report

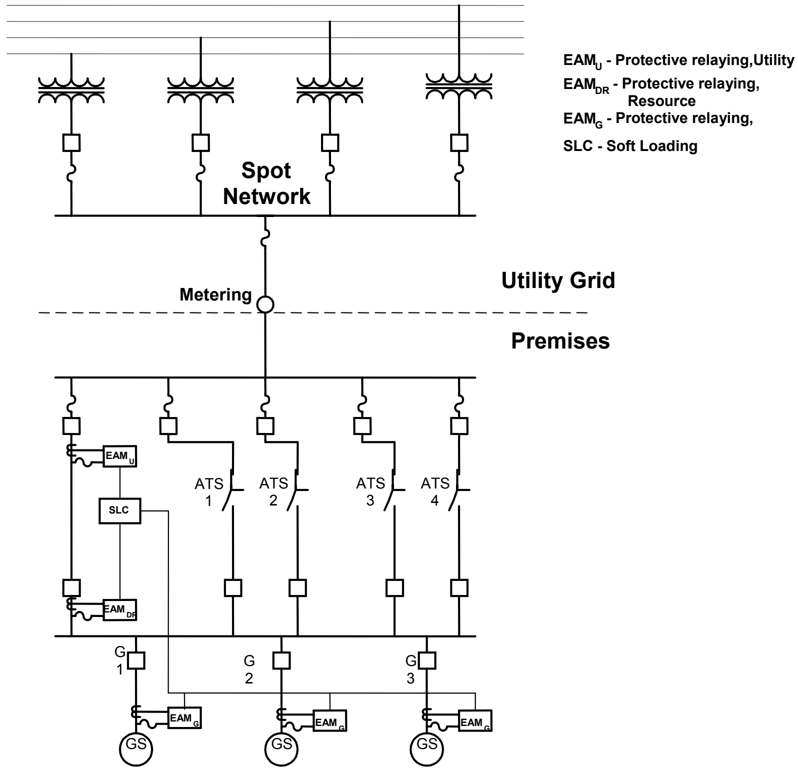

Figure 7. Multiple generators/multiple

- Structure a real time status report
- Archive operating data
- Accumulate trending reports
- Make the system available to an aggregator
- Toggle the operating scenario between islanding and base load.

Since most facility managers are already familiar with the computer windows operating environment, tailoring the system configurations to site specific conditions would be a relatively painless task. As experience grows, increased confidence will enable the manager to finesse the operation so to achieve the optimum cost advantage of the system enhancements. The real issue is keeping the incremental cost of providing this flexibility low enough to provide an acceptable ROI.

Where on-site generation has been contracted to aggregators, they can directly access the facility in a similar manner through the Internet. Operating and reporting scenarios can be tailored to meet the needs. Orders of hierarchy can be established through password privileges to restrict the scope of flexibility at various levels. The facility manager can therefore restrict what the aggregator is permitted to do with the on-site generation system.

Summary

Modern on-site alternate power systems can be retrofitted and expanded to provide an alternative to the high cost of on peak power. The costs for these enhancements have been significantly reduced as a result of the availability of cost effective control strategies that take advantage of the World Wide Web communications environment. One can expect a reasonable ROI on the added infrastructure to take advantage of the sunk cost of installed alternate power systems.